Taxonomy and Ecology of Australian Marine Microalgae

with emphasis on Harmful Blooms and translocation via Ship's Ballast Water

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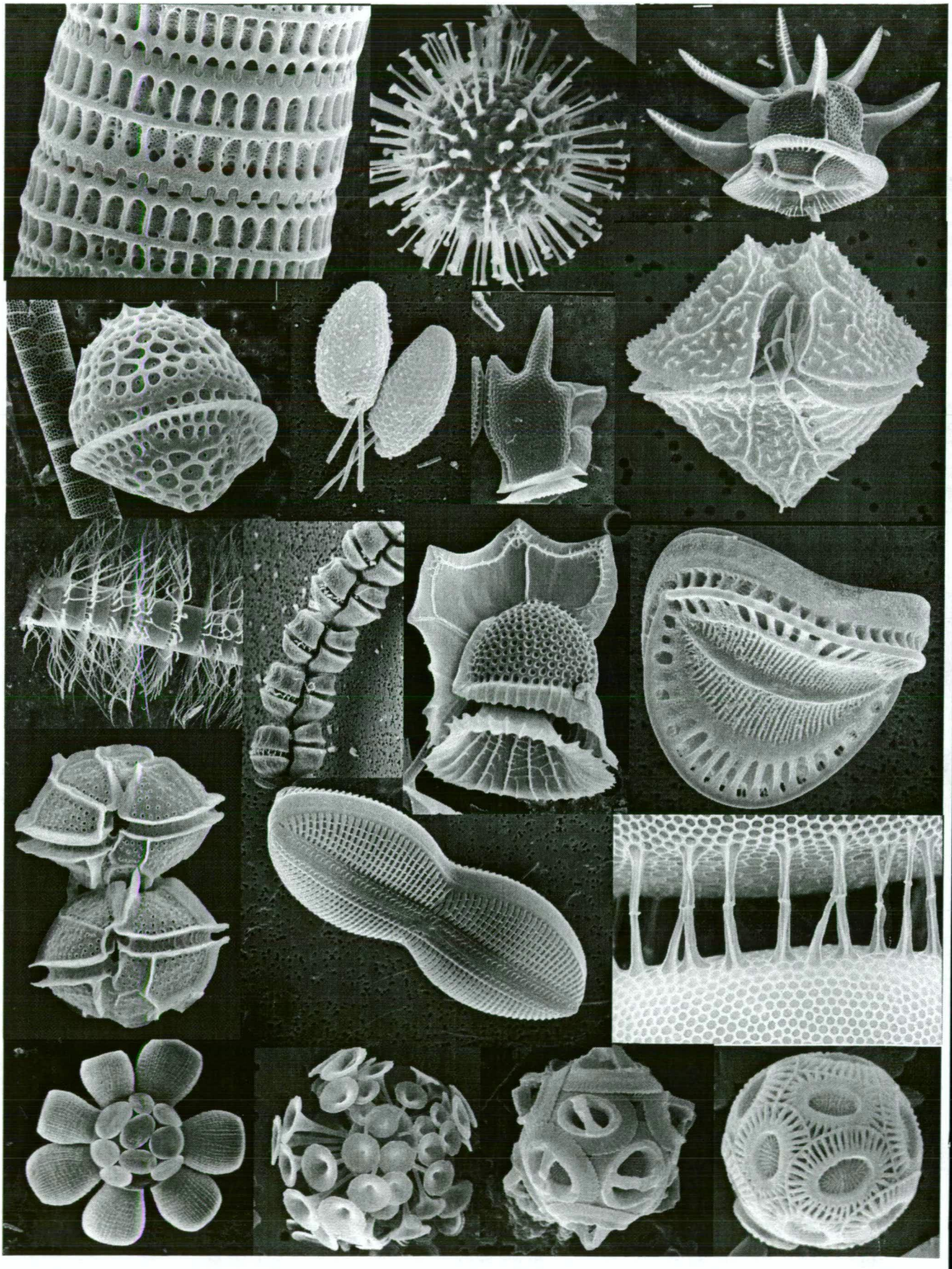

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Summary

Marine Phytoplankton Taxonomy

In 1978, I joined CSIRO Division of Fisheries & Oceanography in Cronulla, NSW, as a Postdoctoral Fellow with a freshly awarded Ph.D. from the University of Amsterdam, Netherlands, for a 1976 thesis on Photosynthetic Pigments, Biomass Estimates and Species Diversity of Freshwater Phytoplankton Populations. While the original purpose of my Australian visit was to work on phytoplankton pigments (work not included here), I quickly recognised the complete absence of modern phytoplankton taxonomic work in the Australian region, which had not been conducted since CSIRO scientist Ferguson Wood left Australia in the 1950s to take up a professorial position at the University of Miami. In the period 1978 –1983, I therefore developed skills in electron microscopy (University of Sydney) and phytoplankton taxonomy (training courses at University of Oslo and University of Washington (Friday Harbour)). This led to the first modern characterization of phytoplankton populations of tropical and temperate, offshore and inshore Australian waters. The phytoplankton ecology of Sydney coastal waters [publications no.2,7,32], the East Australian Current [1,9], the North West Shelf and Gulf of Carpentaria [6], and Coral Sea were documented during this period. My 1978-79 phytoplankton studies in NSW waters have subsequently served as an important baseline against which to assess to impact of the later Sydney sewage outfalls [54]. An important early discovery was the recognition of the importance of nanoplankton (2- 20 μm size) in Australian waters [2], and a number of definitive taxonomic works on a range of microalgal classes (diatoms [5,35], dinoflagellates [13,14,24] coccolithophorids [4], prymnesiophytes and prasinophytes [3]) were published. A very significant proportion of these species were new records for the Australian region. Important taxonomic revisions were instigated which have now become widely accepted, such as the transfer of the diatom *Thalassiothrix frauenfeldii* to *Thalassionema* [8], the separation of the dinoflagellate genera *Dinophysis* and *Phalacroma* [14]. A new freshwater dinoflagellate genus *Thecadiniopsis* was described, which is closely related to marine benthic dinoflagellates from which it is thought to have been derived [10, 69]. A new dinoflagellate species *Gymnodinium microreticulatum* was described which has close affinities to the toxic dinoflagellate *Gymnodinium catenatum* [48] and two new nanoplankton diatoms *Navicula jeffreyi* and *Fallacia carpentariae* were described which have important applications in abalone aquaculture [38].

Harmful Algal Blooms

Upon transfer of CSIRO Marine Laboratories from Cronulla to Hobart in 1984, I devoted myself to the phytoplankton ecology of inshore Tasmanian waters. In my first plankton haul in the Derwent River I newly recognised vast numbers of the toxic dinoflagellate *Gymnodinium catenatum* which has the potential to kill human consumers of shellfish (causative organism of Paralytic Shellfish Poisoning, PSP). As leader of a small research team (4 staff) , the ecology of this species was elucidated and bloom triggers identified [37], cultures were established and the life cycle determined [17], its unknown toxin chemistry defined (collaboration with Tohoku University, Japan [11,33]) and unambiguous evidence was obtained from the identification of cysts in dated sediment depth cores that this nuisance organism had been introduced into Tasmanian waters after 1973 [39]. As a result of my work, Tasmania was the first state in Australia to start monitoring for dinoflagellate toxins in shellfish (collaboration with Tasmanian Departments of Sea Fisheries and Public Health) and this subsequently was extended to Victoria, South Australia, Western Australia, and Queensland. My expertise in harmful algal blooms has also been called upon to address similar toxic dinoflagellate problems in Port Phillip Bay , Melbourne (first identification of the PSP dinoflagellate *Alexandrium catenella* [13], and Port River, Adelaide (first identification of the PSP dinoflagellate *Alexandrium minutum,* not previously known to be toxic [13, 16]) .I was also called upon to coordinate a training workshop on PSP problems caused by the dinoflagellate *Pyrodinium bahamense* in the tropical Indo-West Pacific (Brunei, Philippines [88]), and was the first worker to identify a bloom of the fish-killing raphidophyte *Chattonella marina* in Australian waters and circumstantially link it to a major tuna aquaculture mortality ($45M loss) event in South Australia [42,68] . An invitation to present a plenary lecture at the 1991 International Phycological Congress, North Carolina USA (supported by a Senior Fullbright Fellowship) on the *apparent global increase in harmful algal blooms* led to a state-of-the-art review in the Journal *Phycologia* [31]. This undoubtedly has become my most cited publication. The three key mechanisms raised (increased awareness of previously cryptic species, stimulation by eutrophication or unusual climate conditions; spreading by ballast water and aquaculture translocation) have become standard questions asked with any new unusual algal bloom event. I am well-recognised internationally for my innovative and perceptive work in the harmful algal bloom field, and have been elected on a number of national and international committees:

- UNESCO group of international experts on Harmful Algal Blooms, which led to my editorship-in-chief of an authoritative 551 pp. *Manual on Harmful Algal Blooms* (first edition 1995 [90]; second edition to appear as a *Monograph on Oceanographic Methodology* in late 2002 [94]).

- SCOR Working Group on the *Physiological Ecology of Harmful Algal Blooms*, which led to my associate editorship of an authoritative 662 pp. text on the physiological ecology of harmful algal blooms (first edition 1998 [91]).

- To top this off, I was elected to host the *9th International Conference on Toxic Marine Phytoplankton* in Hobart in February 2000, attended by 526 participants from 47 countries, which led to my editorship-in-chief of a major 518 pp.Conference Proceedings volume [submitted to the printer in May 2001, but published in late 2002 [92] and guest editorship of a special 2001 issue of the international journal *Phycologia* [93].

- Nationally, my production of an *Aquaculturist's Guide to Harmful Australian Marine Microalgae* [1st edition 1991 [89]; 2nd edition 2002] as well as production of a 1988 coffee-table book *Plankton: A Microscopic World* [87] have been most successful.

Role of Ship's Ballast Water in Global Spreading of Algal Blooms

My Tasmanian studies on *Gymnodinium catenatum* dinoflagellate cysts in dated sediment depth cores [39] triggered a major survey of toxic dinoflagellate cysts in ship ballast water [23,26]. My detection of three species of toxic dinoflagellate cysts in ships' ballast waters led in 1990 to the introduction in Australia of special ballast water quarantine regulations (collaboration with the Australian Quarantine and Inspection Service) which are now increasingly being adopted on an international basis. I played a key role in an AQIS Australian Government Scientific Working Group on Ballast Water (since 1989) and am a member of the advisory board of the CSIRO Centre for Research on Introduced Marine Pests (CRIMP) in Hobart (since 1995). Australia has become a leader in the field of management of marine bioinvasions, and the actions now pursued by the International Maritime Organisation (IMO) are largely based on the Australian model. To track down the overseas source populations of introduced Australian toxic dinoflagellate populations, I pioneered the application of molecular genetic markers, initially working with Chris Scholin at Woodshole Oceanographic Institution (in an award winning paper, [36]), and later with my Ph.D. students Chris Bolch (47) and Miquel de Salas (73). In order to assess what constitute baseline dinoflagellate species communities in Australian waters, I and my students instigated Australia-wide surveys of dinoflagellate cysts in sediments from major shipping ports, starting with Hobart [18] and eventually covering Devonport, Launceston, Port Lincoln, Albany, Bunbury, Fremantle, Port Hedland, Darwin, Karumba, Cape Flattery, Moorilyan, Lucinda, Hay Point, Townsville,

Gladstone, Newcastle, Port Botany, Sydney Harbour and Eden. In a very successful collaboration with BHP shipping engineers Geoff Rigby and Alan Taylor, I pursued a number of ballast water treatment and management options using resistant dinoflagellate cysts as a model organism. These ranged from environmentally friendly biocides [30; too expensive], the application of mid-ocean exchange [34; which has become an IMO standard], to (what I advocate is the most effective) the use of ship engine waste heat to kill dinoflagellate cysts at temperatures as low as 38°C [41, 52]. These studies were published in three papers in the prestigious journal *Marine Ecology Progress Series* in 1997,1998, 2000 [39,45,52] and were widely reported also in *New Scientist* and *Science*. This work has been nominated by the Institute of Marine Engineers for the inaugural Stanley Gray award.

Research in Progress

My current research interests (June 2002) are addressing the widespread potentially ichthyotoxic dinoflagellate *Pfiesteria* in Australian waters, toxic PSP dinoflagellate blooms of *Gymnodinium catenatum* in New Zealand waters, the incidence of toxic benthic dinoflagellates (*Prorocentrum, Coolia, Ostreopsis*) in East Coast Tasmanian waters, the phylogeny and morphotaxonomy of fish-killing gymnodinioid dinoflagellates (including new species as well as genus descriptions), and elucidation of the toxic principle of the ichthyotoxic raphidophyte *Chattonella marina*.

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